

# ChainReaction.2

Creepers  
peepers  
AND crawlers

OF THE

Sonoran  
Desert

## Meet the Monster

Dancing with  
Rattlesnakes

The Chemistry  
of Dominance

Fangs, Stingers  
and Tiny Tigers

ASU

# Speeding Tortoises

by  
Danielle Brooks

**Slow**  
and steady,  
the fabled tortoise  
eventually out-raced  
the hare. Times have  
changed. Today, the  
desert tortoise is in  
a race for its very life.  
The competition—  
smarter and much more  
brutal—is human beings.

What is the difference between a turtle and a tortoise? A tortoise is actually one type of turtle that lives on land. Unlike other turtles, tortoises only go to water to drink or bathe.

The Desert Tortoise can live in places where the ground temperature gets above 140°F. It digs underground burrows to escape the heat. A desert tortoise spends at least 95 percent of its life in burrows.



ONCE HOME TO THE FEW and heady, the southwestern United States has experienced a population explosion in recent years.

For example, Phoenix, Ariz., is home to more than 1 million people, making it the nation's seventh largest city.

Surrounding cities, from Scottsdale to Las Vegas, have also traded cactus blooms for population booms. That trend may spell the doom of desert tortoises.

Desert tortoises once roamed freely throughout southwestern California, southern Nevada, and western Arizona. Today they are in trouble.

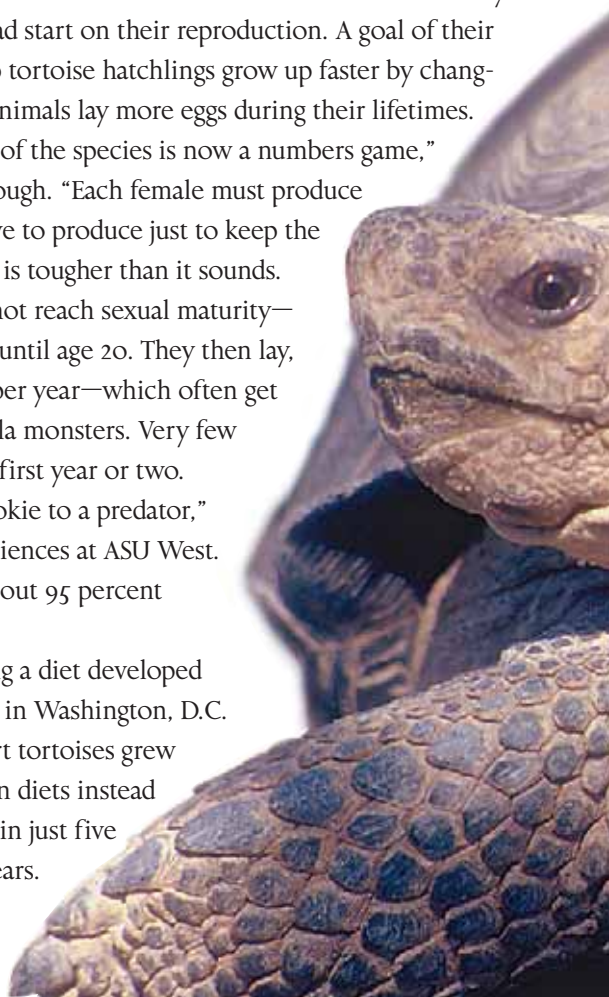
The sad truth is that tortoises do not stand a chance against cars. Hundreds of the animals are crushed every year by cars or off-road vehicles. Pet tortoises released into the wild provide a new danger. These animals often take back deadly diseases to the wild.

That story is the same throughout the world. Tortoise populations in Africa, Asia, and South America shrink as human populations grow.

A group of researchers from The Phoenix Zoo and Arizona State University is working to give tortoises a head start on their reproduction. A goal of their Desert Tortoise Project is to help tortoise hatchlings grow up faster by changing their diets. This will let the animals lay more eggs during their lifetimes.

"For many tortoises, survival of the species is now a numbers game," explains ASU biologist Harvey Pough. "Each female must produce at least two offspring who survive to produce just to keep the population size stable." That job is tougher than it sounds. In the wild, desert tortoises do not reach sexual maturity—when they can produce babies—until age 20. They then lay, on average, three to seven eggs per year—which often get eaten by coyotes, snakes, and Gila monsters. Very few tortoise hatchlings survive their first year or two. "A baby turtle is just an Oreo cookie to a predator," says Pough, a professor of Life Sciences at ASU West. "The death rate of juveniles is about 95 percent before age five."

Pough and his team are testing a diet developed by scientists at the National Zoo in Washington, D.C. Those scientists found that desert tortoises grew faster when they ate high-protein diets instead of greens. They grew to full size in just five years instead of the typical 20 years.



The National Zoo study did have a weakness. Many of the subject tortoises were captured in the wild. As a result, no one knew their exact ages. The ASU/Phoenix Zoo study fixes that problem by using only animals whose age is known.

Researchers started in August 1995 with 24 hatchlings. They divided the tortoises into two treatment groups. One group was fed a traditional zoo salad diet. The second group got high-protein pellets as food.

Tortoises in the high-protein group were switched from zoo salad to the experimental food. They had to be taught how to eat pellets. At first, researchers ground the pellets into a powder and sprinkled it on the tortoises' greens. They were slowly weaned off the salad onto straight pellets. The process took until March 1996.

By November 1999, tortoises in the protein group weighed about twice as much as tortoises that ate salad. The average pellet-eater weighed in at a hefty 800 grams, compared to 360 grams for the salad group.

The tortoise hatchlings in the Desert Tortoise Project were placed in quarantine for a month to ensure a disease-free start. Tortoises from different families were divided equally between the study groups. This allowed the researchers to factor in family differences that might otherwise affect the results. Like human families, some tortoise families are naturally bigger than others no matter what they eat.

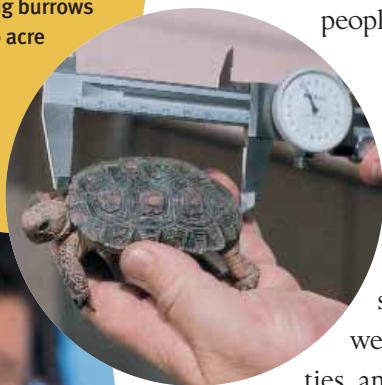


## What do desert tortoises eat in the wild?

The sharp, serrated jaws of the Desert Tortoise look a lot like a bread knife. The jaws are perfect for shredding tough grass and thick, pulpy cactus pads and blossoms. The tortoise gets water from its food and can store a month's supply in sacs under its shell.

George Andrejko photo

ASU scientist Harvey Pough says tortoises play a unique role in the desert. They are big and strong enough to dig burrows in the tightly compacted desert sand. Coyotes, snakes, lizards, toads, insects, and mice all use abandoned tortoise dens for their own retreats. Tortoises dig burrows throughout their 40 to 50 acre ranges. Without them, other creatures would be at the mercy of the desert's extreme temperature swings.



Scientist Smith glues a tiny plastic identification tag to a hatchling.

**“If superjuvies could reproduce at age five, that would be four times faster than in the wild. That would be a clear head start.”**

ELLEN SMITH

This is the first time The Phoenix Zoo has participated in a collaborative, scientifically based research project, according to Mike Demlong, the zoo's curator of ectotherms, or cold-blooded animals. “This study is helping the zoo staff become better scientists,” Demlong says. “That is important, because zoos aren't just about fun and recreation anymore. We're centers of conservation and research. As such, we're about building connections between an increasingly urban population and the natural environment that people are becoming more and more distant from.”

He says that the Desert Tortoise Project “is about inspiring people to live in ways that promote the well-being of the natural world—even if it's as basic as helping people understand why they should try to avoid running over tortoises with their all-terrain vehicles.”

Demlong says The Phoenix Zoo has dedicated special summer and winter habitats to the Desert Tortoise Project, as well as a total of about \$300 per tortoise per year in food, facilities, and veterinary care. “That's a big investment for the zoo, given that we receive no government funding. But it will be money well spent if we can gain clear, conclusive data concerning the proper protein and fiber diet ratios for head-starting healthy, high-quality tortoises,” he adds.

Demlong defines healthy as being free from all diseases—especially respiratory disease and a common shell abnormality called “pyramiding.” Pyramiding has been linked to other high-protein diets. As yet, it has not affected The Phoenix Zoo tortoises.

Demlong defines high-quality tortoises as those able to forage, dig burrows, avoid predators, and generally behave like tortoises in the wild. That is important, he says, or else head-started tortoises will never be released.

ASU's Pough agrees. “The real question is, even if the project's ‘superjuvies’ reach adult size within five years, will they be physiologically and behaviorally mature? Will we have ‘young adults’ or ‘big babies’?” he asks.

This is the point where Ellen Smith enters the story. A scientist at ASU West, Smith studies tortoises of the original National Zoo group at the Desert Tortoise Conservation Center in Las Vegas. Those tortoises are now between nine and 13 years old. Smith's work focuses on social behavior and hormones.

Smith and her Las Vegas colleagues began by pairing up each superjuvie—or head-started tortoise—with an opposite sex adult. Then they watched.

Tortoise “dating” behavior is a pretty strange sight. Normal adult tortoises do a lot of nose-to-nose sniffing. Males “bob” their heads during courtship and bite at the front legs of females. Females show their willingness to mate by staying still. Otherwise, they just walk away.

The research group in Las Vegas watched to see if the superjuvies showed these adult behaviors. They collected blood samples to compare

hormone levels of the superjuvies to levels in adults. Adults that are ready to reproduce have higher levels of sex hormones in their blood than immature tortoises. The scientists also studied all eggs that were laid to find out whether those eggs were fertile.

All the eggs from 1996 did hatch. Most female superjuvies did not lay any eggs; the few eggs they did produce never hatched. Male superjuvies, on the other hand, were able to successfully fertilize their adult partner's eggs.

"Right now, I'd say superjuvie males appear mature while the females seem unable to reproduce," Smith says. "But not knowing the exact age of the National Zoo tortoises makes interpretation difficult."

Smith and the Las Vegas group will continue watching the female superjuvies from the National Zoo to see when they begin to reproduce successfully. However, researchers expect data from the Phoenix study to answer more questions because age, family relationships, and hibernation history will all be known.

"Obviously, our ultimate hope is that superjuvies reach sexual maturity at the age of five or six, and that the females continue producing eggs until age 60 so they can help restore the population," Pough says. "The desert tortoise is a very important species in the desert habitat."

**“If we really can head-start tortoises so that they reach adult size in five years or less, captive breeding and release programs for endangered species may be possible. We hope this method can be used to head-start other tortoise species that are more endangered than desert tortoises.”**

HARVEY POUGH

Desert tortoises lay eggs in May, June, and July. An adult female might lay four to eight eggs in a clutch. She can produce two or three clutches each season. Experiments have shown that when tortoise eggs are incubated at cooler temperatures (79-87°F), they produce all male tortoises. Warmer temperatures (88-91°F) produce all females.

Male desert tortoises often fight each other. The weaker male usually runs away.

The desert tortoise stays cool inside deep burrows that it digs in tightly compacted desert gravel.

In order to get enough drinking water in a dry climate, desert tortoises dig basins in the soil to catch rainfall.

The Desert Tortoise Project is a collaboration between ASU and The Phoenix Zoo. For more information, contact Harvey Pough, Ph.D., ASU West, 602.543.6048. E-mail at [Pough@asu.edu](mailto:Pough@asu.edu). Or contact Mike Demlong at the Phoenix Zoo, 602.914.4373. E-mail at [Mdemlong@phoenix-zoo.org](mailto:Mdemlong@phoenix-zoo.org)





# Tales of Tails

by  
Dennis Durband  
and Conrad J. Storad

South Mountain Park in Phoenix is the largest municipal park in the world. It covers 16,500 acres. The park features unique geology and is home to many different kinds of plants and animals. Matt Flowers tracks chuckwallas in the park with the aid of spotting scopes and radio direction-finders.



A hectare is equal to 10,000 square meters. How big is that? Two football fields side by side would cover nearly one hectare. If you went looking for chuckwallas in other parts of Arizona, you could expect to find about a dozen chuckwallas per hectare.

## WHAT IS THE BEST WAY TO ATTRACT GIRLS?

A bright orange tail can help. It helps a lot if you are a chuckwalla living among the rocks on South Mountain in Phoenix, Ariz.

Matthew Flowers is a graduate student at Arizona State University. He studies chuckwallas. He wants to determine if South Mountain chuckwallas are a brand new species of lizard.

Lots of chuckwallas live on South Mountain. In fact, within the park's boundaries, the concentration of chuckwallas is five times higher than the normal density found in Southwestern deserts. If you go chuckwalla hunting, you might find as many as 60 of the big lizards living in every hectare of territory.

Chuckwallas are big lizards. They grow to almost a foot in length and can weigh as much as 12 ounces. They are the second largest of the 38 lizard species found in Arizona. Gila monsters are the biggest. The average life expectancy for a chuckwalla in the wild is 10 to 15 years, but some of the big lizards live 20 to 25 years.

"South Mountain Park contains a unique population of chuckwallas," Flowers says. "When I first arrived, the question was whether or not the South Mountain population should be considered a new species of lizard."

The Arizona Game and Fish Department currently protects the South Mountain chuckwallas from collectors. The department supports Flowers' research effort. The ASU scientist observes and collects live specimens.

Chuckwallas have very distinct color patterns. The colors provide an ideal trait for studying the big lizards. Male chuckwallas often have different colored tails. The typical tail color is white. Some have black tails. South Mountain chuckwallas are unique. The entire tail on most males is bright orange.

Flowers converted his Tempe backyard into a chuckwalla enclosure. He wants to know if female chuckwallas prefer one color tail to another. To find out, he paints the tails of males. Then he tests specimens within a population or between populations.

Brian Sullivan is an evolutionary biologist and ASU West professor. He also is one of Flowers' advisers. "Matthew's study of geographic variation in chuckwalla mating behavior has generated widespread interest among evolutionary biologists," Sullivan says. "He is providing new understanding of how environmental factors can shape differences in the behavior of males and females of a species."

Flowers makes behavioral observations on South Mountain during all seasons, including the sweltering heat of an Arizona summer.

"We do focal animal observations," Flowers explains. "We pick an animal, watch it for half an hour, and then record its behavior. For example, I watch the males fight. Then I mark down the color patterns of the winner."

Chuckwallas are secretive reptiles. It takes time to gather enough data



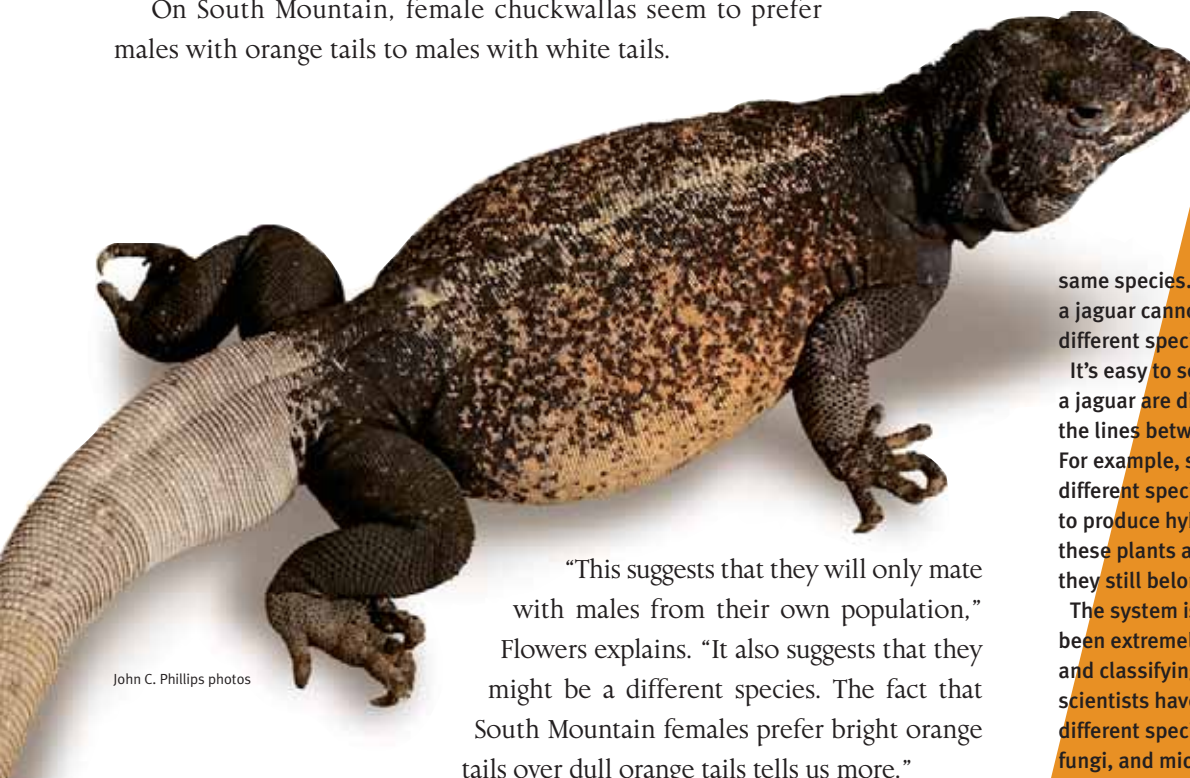
about individual animals. Flowers says that the battles between male chuckwallas can be an amazing spectacle.

"They lock jaws and roll around on the desert floor," he explains. "Chuckwallas also make interesting social displays. Fighting is the ultimate part of social interaction between the males. But they will try to solve issues before fighting. They puff up their bodies and go through other physical displays, including what appears to be a series of rapid pushups."

Flowers logs his observations into a computer database. He uses the computer to compare behavior, such as the number of pushups done among individual chuckwallas over a certain time period.

Catching the big lizards can be painful. Flowers might spend anywhere from five to 90 minutes trying to collect a single lizard. Chuckwallas retreat from danger by wedging into rock crevices and inflating their bodies. A well-entrenched lizard can win the tug of war, forcing the frustrated scientist to retreat, bloody fingers his only reward.

On South Mountain, female chuckwallas seem to prefer males with orange tails to males with white tails.



John C. Phillips photos

"This suggests that they will only mate with males from their own population," Flowers explains. "It also suggests that they might be a different species. The fact that South Mountain females prefer bright orange tails over dull orange tails tells us more."

Flowers says that orange tails may indicate the quality of a male chuckwalla's territory. The orange color is based on carotenoid pigments absorbed from plants eaten by the individual lizard.

Chuckwallas also have good chemical senses. Tiny differences might determine which male a female will select for mating.

"There probably are many factors that affect mate choice by female chuckwallas," Flowers says. "Male tail color is just one."

There are 38 lizard species found in Arizona.

Chuckwallas are the second largest kind of lizards in Arizona. The Gila Monster is number one.

## What is a species?

There are millions of different living things, or organisms, on the Earth. Biologists have a system for naming these organisms by grouping them into categories. The categories allow people to talk about the organisms and study them in a logical way.


A species is one of the categories that biologists use. A species is a group of closely-related organisms that can breed together and produce offspring. A Siamese cat and a Russian blue cat can breed and have kittens. Therefore, they belong to the

same species. A Siamese cat and a jaguar cannot breed—they are two different species of cat.

It's easy to see how a housecat and a jaguar are different, but sometimes the lines between species are blurry. For example, sometimes people breed different species of plants together to produce hybrid crops. Even though these plants are made to reproduce, they still belong to different species.

The system isn't perfect, but it has been extremely useful for naming and classifying life on Earth. So far, scientists have found about 1.5 million different species of animals, plants, fungi, and microorganisms on our planet.—DIANE BOUDREAU

*The Arizona Department of Game and Fish support chuckwalla research at ASU. For more information, visit the ASU Research Magazine Web site—<http://researchmag.asu.edu>*



THE REGAL HORNED LIZARD  
is active during the hot desert day.  
It uses its tongue to slurp up ants.

George Andrejko photos

AT HOME IN THE

# catalyst [Sonoran Desert]

CATALYSTS

make things happen.

They speed up reactions

and make some ingredients combine  
that could not without them.

by Conrad J. Storad

THE SONORAN DESERT IS  
AN ARID, RUGGED PLACE.  
It also is a beautiful place filled with plants and animals.  
Many of these animals and plants are unlike any other  
creatures living on the Earth today.

The Sonoran Desert covers a large region of more  
than 100,000 square miles. It spreads across north-  
western Mexico, includes the Baja peninsula, and  
covers the southeastern tip of California. To the north,  
it stretches over a large section of southern Arizona.

Space Shuttle astronauts in  
orbit photographed the heart  
of Sonoran Desert near Yuma, AZ.



**THE SONORAN DESERT IS A YOUNG DESERT.** Scientists say that it has existed in its current form for less than 10,000 years. It is very hot and dry most of the time. Rain falls on a somewhat regular basis twice each year, usually during the early summer and again during the winter. Rain often falls all at once in violent storms streaked with lightning. Sometimes rain does not fall at all for many months. Total rainfall may amount to only seven to 10 inches in an entire year.

The Sonoran Desert is a living desert. It is not a sea of sand and rocks. There are sand dunes, but only in a few areas. There also are marshy, oasis-like areas called bosques, which form near natural springs. Water in the desert means life. The Sonoran Desert has water in the form of streams and washes from time to time. But water does not often stay around for long.

**Except for the tropical rainforests of South America or Africa, the Sonoran Desert is home to more kinds of plants and animals than any other area of its size. These plants come in many shapes and sizes. So do the animals and insects.**



Tim Trumble photo



**THE AMERICAN KESTREL** is the smallest falcon in North America.

**PIPEVINE SWALLOWTAIL** male butterflies claim and defend perches on ridges and hilltops to keep watch for females.



**THE SAGUARO CACTUS** is the giant of the Sonoran Desert, the only place it grows in the wild.



**THE DESERT WOOD RAT** is also called the Pack Rat. The rodent uses stones, sharp sticks, and cactus spines to protect the entrance to its burrow.



**THE DESERT IGUANA** is active at temperatures as hot as 115 degrees. It can grow more than a foot long.

John Alcock photo

**BIG-EARED BATS** hunt moths during the night. Huge ears allow them to fly and locate food by sound, using the echoes of their ultrasonic squeaks. Some bats can catch up to 600 mosquito-sized insects per hour.



Desert animals  
have adapted  
to live in hot,  
dry conditions.  
Can you explain  
ways creatures  
survive in  
the desert?



**THE MYDID FLY** is active and mates in the hottest part of the summer.

#### KANGAROO RAT



**THE ANTELOPE JACKRABBIT** is actually a hare, not a rabbit at all. Jackrabbits rarely drink water. They get all the moisture they need from the plants they eat. Jackrabbits run in speedy bursts up to 50 miles per hour. The Jackrabbit's foot-long ears help control body temperature. During hot days, the long ears stand straight up. Inside the ear's thin skin, a network of blood vessels gives off heat, cooling the animal's body. On cold days, the ears lay back close to the Jackrabbit's body.



**THE GILA MONSTER** is the largest and only venomous lizard found in the United States. The big lizard's teeth look like tiny grooved daggers. Despite a fierce reputation, Gila Monsters actually are quite shy. They spend most of their time hiding in desert burrows stolen from mice, squirrels, or other small rodents.

George Andrejko photos

Desert plants are adapted to survive and flourish in hot, dry conditions. The roots are shallow nets or deep straws that slurp up as much moisture as possible following a rare rainstorm. Most have small waxy leaves or sharp spines.

The Sonoran Desert's animals and insects are just as tough. Many desert mammals and reptiles are active only at dusk and again at dawn. For this reason, it is rare for humans to meet a javelina, jackrabbit, Gila Monster, or rattlesnake while hiking during the day.

Bats, many snakes, most rodents, foxes, coyotes, skunks, and other large desert mammals are totally nocturnal. They sleep in a cool cave, den, or burrow during the hot desert day and hunt at night when the temperature is cooler. Many desert birds are active during the day. But they always perch in the shade.

Desert toads actually sleep most of the summer. They stay dormant deep underground in moist soil until the summer rains fill the ponds. When they emerge, they find mates and lay eggs quickly. The toads spend lots of time eating and drinking to replenish their body reserves of food and water for another long period of sleep.

Desert animals have developed many different ways to find precious water. Some never drink water at all. They get all the moisture they need from the plants or insects they eat. The kangaroo rat and other amazing desert rodents can actually make their own water from the digestion of dry seeds. They will not drink water, even if it is available by the bowlful.



**THE DESERT COTTONTAIL** likes to munch on grass, mesquite, and cactus.





**THE COLLARED PECCARY** is a piglike animal, but not actually a pig. The name refers to the band of grayish-white fur around its neck. Heavy, bristly hair covers a thin, muscular body. In Arizona, a collared peccary is known as a Javelina. Javelinas have tough, leathery snouts, which allow the animals to eat cactus and other spiny desert plants without injury to their mouths.

George Andrejko photos



**TURKEY VULTURES** have a sinister reputation because they eat stuff that would make you hurl—carcasses of dead animals.



**THE RINGTAIL CAT** is not really a cat. Closely related to raccoons, ringtails are curious and active at night, sometimes stealing hikers' food supplies.



**THE BOBCAT** snoozes on a warm afternoon just like a housecat. But don't try to pet it!

# catalyst

**THE ROADRUNNER** is the world's fastest-running flying bird. It prefers running to flying. About the size of a skinny chicken, the speedy birds can take 12 steps in one second. Roadrunners have been clocked zipping across the desert at speeds up to 15 miles per hour.



**TIGER BEETLES** are fast-moving predators that catch and eat other insects. They live in deserts and tropics around the Earth. In India, people make jewelry from the colorful wing cases.

**THE LONE COYOTE** howling at the moon is a symbol of the American West. In reality, Coyotes are not solitary animals. They mate for life and often hunt in packs, mostly at night. Coyotes use at least 10 different sounds to communicate, including barks, yips, growls, and howls. Coyotes are speedy runners. They cruise at 25 to 30 mph and can sprint at 40 mph for short bursts, which is handy for catching rodents, rabbits, and small deer.

**THE WESTERN BANDED GECKO** feeds at night on spiders and insects.



**THE TARANTULA HAWK** is a big wasp. The female uses a huge stinger to paralyze tarantulas and other large spiders. Males do not sting. The wasp lays a single egg on the body of the paralyzed spider. When the egg hatches, the maggot-like larva burrows into the living spider and begins to feed. The spider is helpless. It actually may live for weeks or months as the wasp larva devours him from the inside out. ASU biologist John Alcock studies the big wasps. He marks harmless males with paint. Alcock has tracked a single wasp for up to 40 days in the field.



John Alcock photo

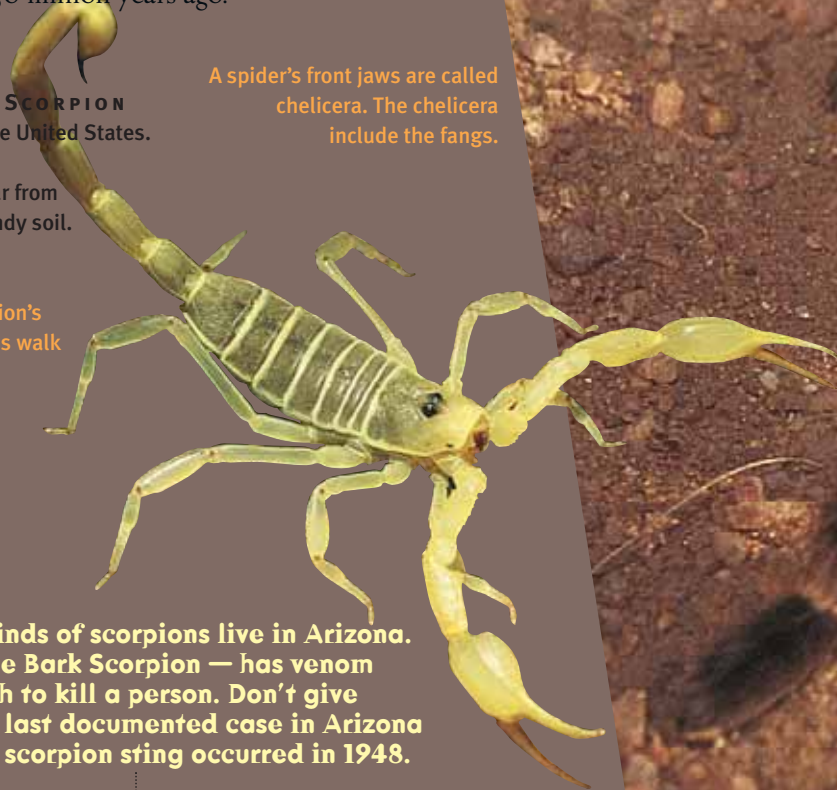
**TARANTULAS AND SCORPIONS ARE ARACHNIDS.** Arachnids belong to the largest group of animals now living on the Earth. Arthropoda is the scientific name for this group, which scientists call a phylum. Creatures in this group are called arthropods. The phylum Arthropoda includes arachnids such as spiders, scorpions, ticks, and mites. It also includes centipedes, millipedes, crustaceans such as crabs, shrimp, and lobsters, and millions of kinds of insects. Fossil evidence indicates that ancestors to modern scorpions might have been swimming in ancient oceans as long as 450 million years ago.

**cat  
lyst**

**THE GIANT DESERT HAIRY SCORPION** is the largest scorpion living in the United States. It can grow up to 6 inches long. Desert scorpions never venture far from the burrows they dig in loose, sandy soil.

A spider's front jaws are called **chelicera**. The **chelicera** include the fangs.

"Chela" is the name for the scorpion's pincer-like appendages. Scorpions walk with their chela extended.



**More than 35 different kinds of scorpions live in Arizona. But only one species — the Bark Scorpion — has venom potentially strong enough to kill a person. Don't give yourself nightmares. The last documented case in Arizona of a person dying from a scorpion sting occurred in 1948.**

Paula Jansen photos

# fangs & stingers

**TARANTULAS AND SCORPIONS** are cousins. They may look like monsters from outer space, but they actually are very shy creatures. They want nothing to do with humans. There are no tarantulas in Arizona or the United States that are considered dangerous to humans. You are in more danger from fainting and hitting your head than you are from the bite of a desert tarantula.

MEXICAN REDKNEE TARANTULA

Tarantulas catch insects and tear them into pieces. The pieces are rolled into a large "food ball." The spider then gushes digestive fluids onto the ball and slurps in the gooey bug stew. Hard pieces are left behind.

In the Sonoran Desert, tarantulas spend most of their lives living inside small burrows that they dig in the desert soil. They leave the burrow at night to hunt for crickets, grasshoppers, beetles, cockroaches, and other small creatures.

Better to be a girl? Most male tarantulas only live between six and 18 months. Female tarantulas can live for 20 or 30 years, depending on the species.

# Tracking

Emily Taylor's area of research is called behavioral neuroendocrinology. She studies how hormones trigger an animal's brain to command certain actions, such as breeding.

by Kristine S. Wilcox

## Herpetology: The study of reptiles and amphibians

CAMPING GEAR AND RESEARCH EQUIPMENT cram the back of Emily Taylor's truck. Beside her sits a plastic bucket secured with a screw-top lid. Two female Western diamondback rattlesnakes are snoozing inside.

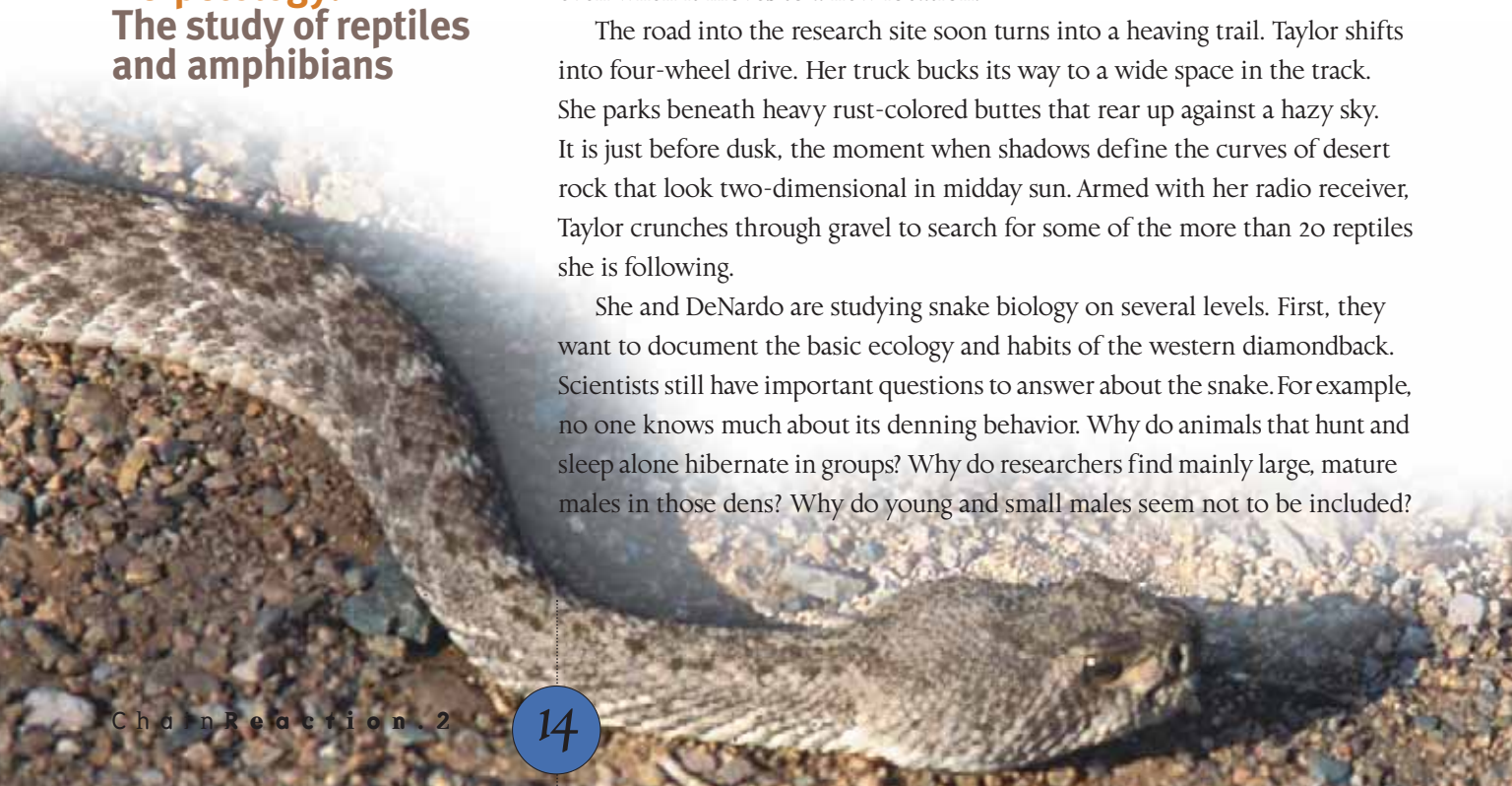
Taylor is crossing reservation lands between Phoenix and Tucson to return the snakes to the wild. She is headed toward the research site she and her advisor, veterinarian Dale DeNardo, have staked out on land near the Tortalita Mountains. Earlier that week in their ASU laboratory, the two scientists surgically implanted a radio transmitter under each animal's ribs. Each transmitter broadcasts a beeping signal at its own unique frequency. Using a receiver, Taylor and DeNardo can locate the snakes in the field by following the signals.

This technology is called radio telemetry. The technology really helps scientists who study reptiles. Just imagine trying to find the same snake twice. In the past, researchers marked rattlesnakes by painting or injecting their rattles with paint in coded patterns. That helped them to recognize a snake if and when they were lucky enough to find it again.

Laboratory conditions can cause animals to behave differently than they would in the wild. To study patterns in animal behavior, scientists must watch the animals over time in their natural environments. Unfortunately, this makes it very hard to keep track of them. Radio telemetry lets scientists find an animal even when it moves to a new location.

The road into the research site soon turns into a heaving trail. Taylor shifts into four-wheel drive. Her truck bucks its way to a wide space in the track. She parks beneath heavy rust-colored buttes that rear up against a hazy sky. It is just before dusk, the moment when shadows define the curves of desert rock that look two-dimensional in midday sun. Armed with her radio receiver, Taylor crunches through gravel to search for some of the more than 20 reptiles she is following.

She and DeNardo are studying snake biology on several levels. First, they want to document the basic ecology and habits of the western diamondback. Scientists still have important questions to answer about the snake. For example, no one knows much about its denning behavior. Why do animals that hunt and sleep alone hibernate in groups? Why do researchers find mainly large, mature males in those dens? Why do young and small males seem not to be included?



A woman in a light-colored shirt and dark pants is standing in a desert landscape, holding a long-handled tool. She is surrounded by saguaro cacti and dry vegetation under a clear blue sky. A large yellow graphic element, resembling a stylized 'S' or a bracket, is overlaid on the left side of the image.

Taylor wants to know exactly what happens in a female snake's brain that tells her she has enough fat to breed. Taylor and DeNardo suspect that a hormone called leptin is involved. Scientists know that leptin helps to regulate eating and reproduction in mammals. They know that reptiles produce leptin. But they don't know what function the hormone plays in the reptile body.

A decorative element consisting of a horizontal row of small, solid blue circles, spaced evenly across the width of the page.

The ASU scientists weigh the snake each time they recapture an animal. By comparing a female's pre- and post-birthing weights, they can figure out how much fat and protein snakes invest in their babies. Two knots snarl the research question. Taken alone, a female's weight change does not show



## Studying reptiles gives you a great evolutionary

### Occupational Hazard

**“The term ‘usually’ should never be applied to venomous reptiles,” cautions rattlesnake researcher Emily Taylor.**

For example, snakes being coaxed into a tube *usually* strike at the tube, not the person holding it. But that didn’t matter much when “Lucifer the Jumping Snake” decided one day to sink its fangs into Taylor’s hand instead.

“He jerked his head out,” Taylor says, “and sprang up to bite my hand. Usually the snake won’t behave this way. He’ll strike the tube, because it’s the closest thing to his face.”

Nature is never entirely predictable. Forgetting that in Lucifer’s case, says Taylor, was her mistake.

Worldwide, every year, several hundred thousand people are bitten by venomous snakes. Of those, some 20,000 die. Most deaths occur in Third World countries with poor access to medical treatment. Properly treated, snakebites in developed countries cause death in less than 1 percent of victims.

In the United States, most bites occur when untrained people handle snakes in the wild. Some victims die simply because they refuse medical care. Of nine snakebite deaths in Arizona in recent years, three happened to victims who refused treatment.

Almost all the old folk remedies for snakebite are useless or dangerous, according to experts. You should never cut into a bite wound to suck out venom, or apply a tourniquet unless a doctor says to do so. →→→

how much energy she has put into reproduction. Exercise or diet rather than pregnancy might have caused the change. Also, the researchers need to know how much of the weight change is because of protein and how much is fat.

To find out, Taylor and DeNardo are using a technique commonly used to measure body fat on humans. The method involves sending an electrical signal through the body. The signal travels at different speeds through fat and protein. After some number crunching, this information lets researchers estimate the animal’s body fat percentage. Armed with this measurement, the scientists will then factor in the animal’s movements (exercise) and the food supply (her diet). They can then estimate how much body fat energy the female has used to make babies.

Every three to four weeks, the researchers draw blood from the reptiles to measure hormone levels. Taylor has one priority on this particular field visit. She wants a blood sample from a female diamondback that she has been trying to catch above ground for three weeks. With reptiles, the question is always, is the animal up on the surface? Or is it down in a burrow? Radio equipment may pinpoint an animal’s location. But if a rattlesnake is curled up in a burrow, Taylor cannot just ring the bell and ask the snake to come out.

With her blonde ponytail swinging, a coiled serpent tattoo on her ankle, Taylor strides along the soft-gravel washes that curve through the desert like highways. Taylor holds the simple tools that protect her. In one hand is a pair of plastic snake-handling tongs. In the other, a clear plastic tube, cloudy with scratches, that is about as long as her forearm. A student intern lugs the plastic bucket holding the snakes Taylor is returning.

Taylor always listens for the hissing rattle of a snake. She listens close in washes where the scales of the diamondback blend into the gravel, and around patches of prickly pear cactus, in which the vipers often seek burrows.

“The real danger out here is getting careless and stepping on a snake,” she says. Suddenly, Taylor spots a snake. Stretching ahead of her in the wash is a male diamondback, about three-and-a-half feet long. “Oh look at you, bad boy,” Taylor says. “You are a beautiful boy.” She rushes toward the snake, which tries to escape into the brush.

Rattlesnakes are slow. They cannot crawl more than about three miles per hour. Taylor clamps her tongs around the snake’s body, holding it at full arm’s length. The animal begins the defensive displays that it uses against predators. Its muscled body thrashes. Its rattles clash furiously against one another. Its pink cave of a mouth gapes and hisses. Foul smells seep from its cloaca.

With her right hand controlling the tongs, Taylor uses her left to bring the tube toward the rattler’s head. Again and again the snake strikes the plastic

perspective,” Emily Taylor says.  
“Remember, reptiles gave rise to mammals.

with sharp snaps. The scientist is trying to lure the diamondback into the tube. Finally it goes in, shooting about half the length of its body into the plastic pipe. Now Taylor grips the tube and the tail end of the snake in one hand. The tail hangs free, while the dangerous head is trapped in the tube.

“The snake could turn around in the tube, shoot back out and get your hand,” Taylor explains. “Never take your eyes off a tubed snake.” She learned this lesson the hard way (*see sidebar*).

Scientists don’t know why snakes enter the tube. “It may remind them of heading into a burrow to escape a predator,” says Taylor. “Maybe it’s an instinctive defensive move. They’ll fight going in, but sooner or later they all go in.” Besides, she says, “They’re not super bright. The tube is in the forward direction, and eventually they just go forward.”

Taylor pulls a syringe from her pack and bites the cap off the needle. The intern takes the tube, and Taylor works the needle into the snake’s smooth skin, seeking a vein near the rattles. She finds it and blood fills the syringe. With another syringe she shoots acrylic paint into its rattles to identify it with a three-color code.

Rattlesnakes are cold-blooded creatures. A snake feels cool to the touch. Its body is very muscular. The underside feels slick as the hull of a fiberglass boat. On top, you can click a thumbnail down the edges of the scales.

Taylor dumps the diamondback tail-first into a bag, then into the bucket with the others. Later, she will weigh it, record its location, and return it to the discovery site. This is the only new snake Taylor finds on this trip, but she does find the female that has been eluding her. Taylor is thrilled to draw the snake’s blood, saying how pleased her advisor will be that she got it.

Through the night and again the next morning at daybreak, Taylor doggedly tracks each animal she must account for. She never loses her way, although she crosses several square miles. The heat and exercise do not seem to tire her. Her passion for her work keeps her energized.

Lots of people might ask why Taylor is interested enough in snake hormones to wrestle with rattlers. She points out that, for human beings, all biology leads to self-understanding.

“Studying reptiles gives you a great evolutionary perspective,” she says. “Remember, reptiles gave rise to mammals. Besides,” she adds, “some of the biggest discoveries in science occur during basic research, kind of by accident.”

“I’m not saying that I expect to find the cure for AIDS by studying snake hormones,” Taylor admits. But she does expect to add facts to the scientific understanding of snakes.



**SNAKE SURGERY** Emily Taylor operates on a captured rattler to implant a radio transmitter.

Poison control experts agree that the best first aid for snakebite is to keep the victim calm and warm to prevent shock, and to seek medical help immediately.

In Taylor’s case, she received standard treatment with antivenin—a serum that neutralizes the poison.

She feared antivenin more than snake venom. Antivenin is made from horse serum. Horse serum causes intense allergic reactions in 98 percent of all patients. Symptoms can include rashes, fever, and joint stiffness. Doctors treat the reaction with steroids and antihistamines. Taylor did suffer a reaction after her treatment with the antivenin. But she responded quickly to treatment and was handling snakes again within a week.

“I have a renewed sense of care and appreciation for these snakes, now,” the ASU scientist says. She intends to keep a “much larger buffer zone” between herself and her snakes in the future. Kristine S. Wilcox

# Terrible OF THE DESERT Tigers

IN THE SONORAN DESERT, some tigers hunt during the day. Others hunt only at night. All desert tigers use excellent eyesight to locate their prey, and then use amazing speed to run it down.

The hunted creature has little chance. Once caught, the tiger crushes it with huge, sickle-like jaws, and then tears it into pieces. The tiger pours powerful digestive juices from its mouth onto the bits and pieces. Once the pile of pieces is melted into a nice, gooey mush, the tiger rolls it all into a large meatball. Then it is time to chow down.

Tigers in the Arizona desert? No way, you say. Believe it. But these tigers are not giant cats. They are beetles. Their food of choice includes ants and termites and small insects of all kinds.

David Pearson studies these fierce desert hunters. Pearson is an ecologist and conservation biologist at Arizona State University. Tiger beetles, he says, are fascinating, colorful predators. The insects are extremely popular among amateur entomologists. Often brightly colored in greens, maroons, or metallics, tiger beetles are the beauty queens of the insect world.

Pearson has circled the globe for his research, studying beetles in South America, India, Africa, Europe, Indonesia, and the United States.

Arizona is famous for its variety of tiger beetles. The state is home to 36 different species, which live everywhere from the Chiricahua Mountains in southern Arizona to the North Rim of the Grand Canyon. The beetles are especially fond of the Sulphur Springs Valley in southeastern Arizona, where 18 different species live. That is one of the highest concentrations of species in all of North America.

Tiger beetles in Arizona grow from 10 to 25 millimeters long. Most are brown or green with stripes. Most are active during the day. Some are large and black and active only at night. The best time of year to see tiger beetles depends on where you look.

The insects are active from February to April in Sedona and along the Mogollon Rim near Payson. In July, they can be found in the White Mountains. In southern Arizona, tiger beetles are active at the start of the summer monsoons.

Pearson studies tiger beetles because they lend themselves easily to conservation studies. These insects make good bioindicators. A bioindicator is a species that serves as a representative sample of its ecosystem.

Bioindicators allow scientists to make predictions about the ecosystem without studying every species in it. Tiger beetles are highly sensitive



*Cicindela oregona maricopa*—  
Kim Wismann Photo

BY DIANE BOUDREAU



About 2,300 species of tiger beetles (family Cicindelidae) exist worldwide. They live everywhere there is land, with the exception of Antarctica, Tasmania, and some of the most remote oceanic islands.

Tiger beetles primarily live in tropical areas. The United States is home to 120 different species.

All the beetles shown here were found in Arizona.

to changes in their environment, an important characteristic.

"In conservation biology we're always short of money, time, and personnel. We need to make policy decisions. Bioindicators provide a quick way to find answers with a high degree of accuracy," explains Pearson.

"Bioindicators are kind of like the canaries in a coal mine," explains Pearson. "The canaries were very sensitive to methane gas—much more so than human beings. These big burly miners would carry down these little cages with canaries.

If the canary all of a sudden keeled over, people ran quickly out of the mine, because they didn't have a lot of time, but at least they had some kind of warning as an indicator of the danger."



Paula Jansen photo

Tiger beetles vary in size.

The smallest lives in Borneo and measures 6 millimeters, about the length of a housefly. The largest lives in southern Africa. It measures up to 45 millimeters, about the width of a tea bag.

Tiger beetles come in many colors. Some are plain black, but others are stunningly decorated in metallic green, brown, maroon, or purple, often with stripes or spots. All tiger beetles have long, thin mandibles shaped like sickles, which help them capture prey. Tiger beetle larvae use their mandibles to dig tunnels in the ground, where they wait for small insects to pass close enough for capture. The larvae stay in their tunnels from one to three years before emerging as adult beetles.

**"You can't just choose bioindicator species because you like them, because they're soft and furry."**



*Cincindela pulchra*—Kim Wismann photo

An Australian tiger beetle takes the prize as the fastest runner of all the arthropods, a group that includes all insects, crustaceans, and arachnids. This beetle can move at 9 kilometers per hour (5.6 miles per hour), or 170 body lengths per second. If it were the size of a racehorse, the beetle would be running about 120 miles per hour. Consider this: a human traveling 170 body lengths per second would have to run about 338 miles per hour, or 544 kilometers per hour! The tiger beetle is a tough bug to catch, or to outrun.

# Going Buggin'

by Diane Boudreau

**THE HOVER FLY** looks and acts like a bee. It's a trick to make a harmless animal appear uninviting to predators.



John Alcock photos

## WHAT IS AN INSECT?

Insects have three major body sections: Head, thorax, and abdomen

The head contains the one set of large compound eyes, mouthparts, and one pair of antennae

Six walking legs and one or two pair of wings attach at the thorax

## DARKLING BEETLE

assumes the warning position. This common desert beetle protects itself by firing a chemical that smells and tastes bad. Have you seen these beetles in your neighborhood?



IT COULD BE HALLOWEEN AT BRIMHALL JUNIOR HIGH SCHOOL IN MESA. Kids are emptying bags. They count and compare their loot like hungry trick-or-treaters. However, they are not finding candy bars and lollipops in the bags. More like a bunch of ants and a handful of beetles.

Perhaps there are a couple of crickets in the mix. Once in a while there is a real prize—a giant centipede or even a scorpion!

These treats are no trick. The bags of bugs are actually part of David Boomgaard's science class. They are also part of something bigger.

Brimhall is just one of several schools taking part in the Central Arizona–Phoenix Long-Term Ecological Research project—CAP LTER for short. Scientists from Arizona State University's Center for Environmental Studies and the CAP LTER project are studying how city life in the desert affects our air, water, plants, and animals—including bugs.

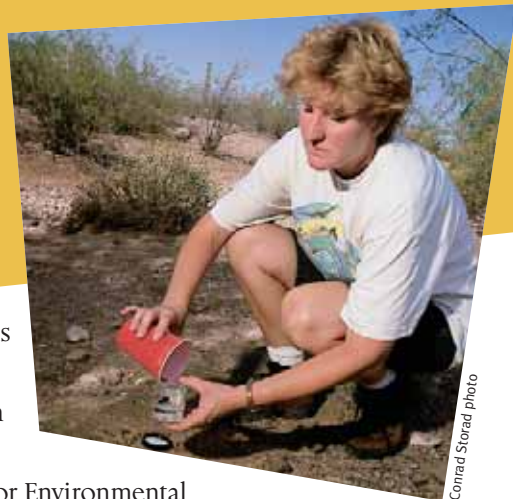
The bug work is known officially as the Ground Arthropod Study. Arthropods include insects, arachnids (such as spiders and scorpions), crustaceans (lobsters, shrimp, and crabs), and myriapods (centipedes and millipedes). Ground arthropods are creatures that crawl on the ground. They do not fly or swim.

Most people try to squash bugs. They shouldn't. Insects are actually a very important part of the ecosystem, says Nancy McIntyre, the ASU scientist in charge of the arthropod study. "There are more different types of bugs than any other kind of living organism on the planet," she says. "They're the most diverse group of critters in the world."

Arthropods also play important roles in the environment. They are critical links in the food chain, both as predators and prey.

They also aerate soil, pollinate crops, and do a variety of other essential jobs.

There are lots of LTER sites all over the United States. Scientists have been doing long-term research on different habitats for more than 20 years. But the Phoenix LTER site is new. It is one of only two sites located in cities. The other city site is Baltimore, Maryland.



Conrad Stord photo

CAP LTER SCIENTISTS COLLECT BUGS FROM 24 SITES.

THE SITES ARE DIVIDED INTO SIX DIFFERENT TYPES OF HABITATS:

☉ HOMES WITH LAWNS

🌵 HOMES WITH DESERT LANDSCAPING

\* INDUSTRIAL AREAS

🌾 FARMLAND

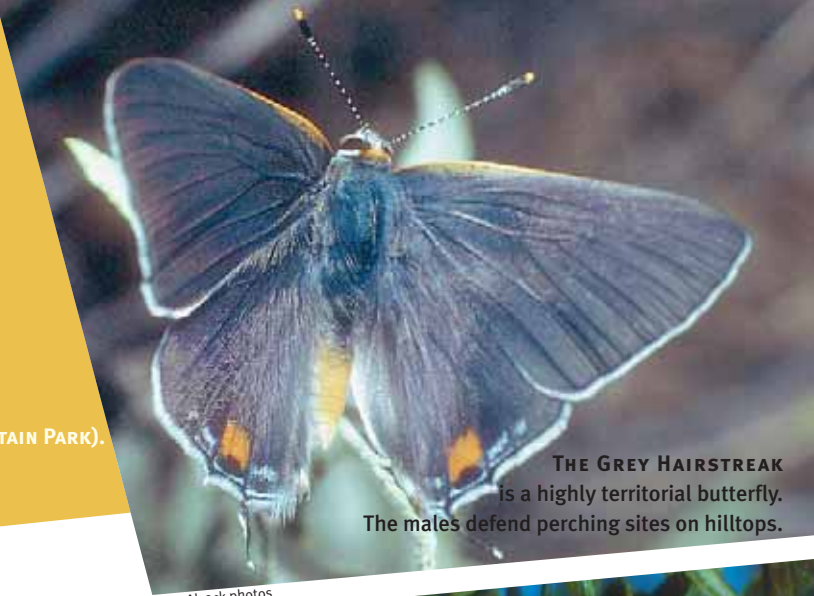
🏡 DESERT PARKS WITHIN THE CITY (LIKE PAPAGO PARK)

🏡 DESERT PARKS ON THE EDGE OF THE CITY (LIKE ESTRELLA MOUNTAIN PARK).

PHOENIX-AREA SCHOOLS THAT PARTICIPATE IN THE BUG STUDY

ADD ANOTHER CATEGORY TO THE MIX:

🏫 SCHOOLYARDS



**THE GREY HAIRSTREAK** is a highly territorial butterfly. The males defend perching sites on hilltops.

John Alcock photos

### WHAT IS AN ARACHNID?

Arachnids have only two major body sections: Cephalothorax and abdomen.

Head and thorax are fused to form the Cephalothorax; a thin waist connects the two body parts.

Eight walking legs

Many eyes, as many as 6 or 8

No antennae

No wings



**BLACK WIDOW** venom, drop for drop, is 15 times more powerful than that of a rattlesnake.

But a rattlesnake is much more dangerous because it produces much more venom.

Marty Cordano photo

“Bugs in cities have been under-appreciated until very recently,” McIntyre says. Now, CAP LTER researchers are finding that urban areas are home to more than just roaches and ants. “It’s pretty amazing that a city as large and as sprawling as Phoenix has such a diverse bunch of bugs. So far, we’ve captured nearly 90 types of arthropods here,” says McIntyre.

CAP LTER scientists collect bugs from 24 sites. The sites are divided into six different types of habitats. Phoenix-area schools that participate in the bug study add their own special habitat: schoolyards.

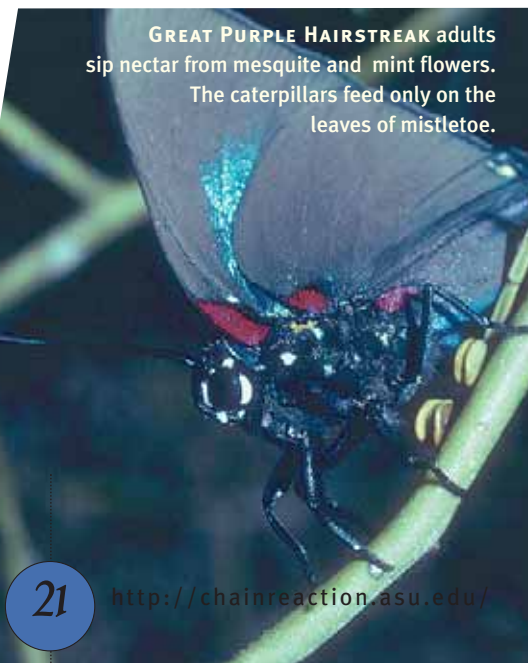
“We wouldn’t normally have access to a whole bunch of schools,” McIntyre says. “We wouldn’t have the people power, we wouldn’t have the time, and we wouldn’t have the money.” So teachers and students contribute a lot to the project. Twenty schools are involved in the project at this point, almost doubling the number of sites being studied.

CAP LTER’s Ecology Explorers program works with local schools to teach kids about ecology and get them involved in the experiments. Monica Elser is an education liaison for Ecology Explorers. She says that Arizona students basically do the same research as the CAP LTER scientists.

The first step is to set traps to catch the bugs. Students bury plastic cups so that the tops are level with the ground. Bugs fall into the cups, but they can’t climb out because the sides are too slippery.



**THE BUPRESTID BEETLE** is a wood-boring insect. Some types specialize in feeding on the pungent creosote bush.



**GREAT PURPLE HAIRSTREAK** adults sip nectar from mesquite and mint flowers. The caterpillars feed only on the leaves of mistletoe.

THE LONG-HORNED WOOD BORING BEETLE male defends saguaro fruits in order to mate with females attracted to the food.

**A PAIR OF DUNG BEETLES** just making a living. They roll a ball of cow dung to a burrow where they lay eggs. The dung will feed the grubs when they hatch.



John Meek photos

## Bugged by Bugs

**It flies. It crawls.** It is small and funky-looking. It's a bug, right? Well, not exactly.

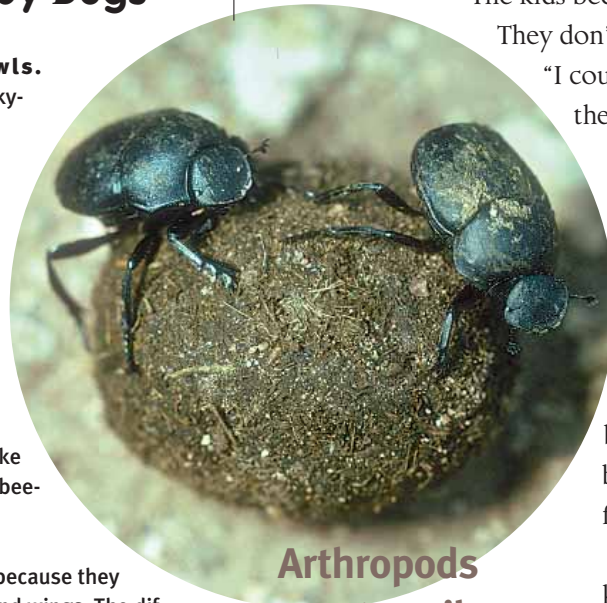
Most people use the word "bug" to refer to all insects. But technically, not every insect is a bug. True bugs, as they are called, do not include such buglike creatures as ants, beetles, or flies.

True bugs look a lot like beetles, because they have hard shells and wings. The difference is in their mouths.

Beetles have mouths designed for chewing. True bugs have long snouts designed for sucking sap from plants.

Flies, mosquitoes, yellow jackets, midges, and gnats often make it a habit to bug people. The next time they start bugging you, remember that they are not true bugs at all. They are insects. Tell them to "Bug Off."

To learn more about the CAP LTER Ecology Explorers program, contact Monica Elser at 480.965.6046 or Susan Williams at 480.965.1961. E-mail to [ecology.explorers@asu.edu](mailto:ecology.explorers@asu.edu). Or, visit the Ecology Explorers Web site—<http://caplter.asu.edu/explorers/>



**Arthropods**  
**aerate soil,**  
**pollinate crops,**  
**and do a**  
**variety of other**  
**essential jobs.**

After collecting the bugs, the kids immediately put them into labeled Ziploc bags. Then they freeze the bags, bugs and all.

Elser says the freezing is very important. It is difficult to study bugs closely enough to identify them when they are moving. Freezing is also an important safety measure, because students occasionally catch scorpions and other venomous arthropods.

Students identify the creatures using a key that CAP LTER provides. They catalogue the bugs by order, such as *Hemiptera* (true bugs) or *Coleoptera* (beetles). The students count how many of each type they find, and then send the data to the CAP LTER Web site on the Internet.

"The kids become experts at identifying the insects.

They don't need the keys after a while," Boomgaard says.

"I couldn't even identify them before I joined the program, and I'm a biology teacher!

"We mostly find beetles and ants. Every once in a while we get some surprises," he adds. "We've caught some bees, which are a surprise because normally they just fly away. We've caught crickets and cockroaches. We even get the odd gecko or two in the cups."

Elser says that most students find lots of beetles, grasshoppers, crickets, roaches, true bugs, and ants. Once in a while, students will find a scorpion or giant desert centipede as well.

McIntyre hopes the program will teach kids not to just kill bugs automatically. "A lot of people are really afraid of arthropods," she says. "They think they're going to bite or sting, but most of them don't. I know from personal experience that when people are afraid of things they tend to kill them. A great example is dragonflies. People are scared to death of dragonflies. But dragonflies are completely harmless."

Not only are most bugs harmless, many of them are pretty, too. "There are a lot of beautiful patterns that you can only see up close," Elser says.

What do Boomgaard's Mesa junior high students think of the project? "I remember a kid saying last year, 'This is really cool. We don't just learn about science, we go out and actually do it,'" Boomgaard says.

The CAP LTER scientists are just as happy about the project. "All the students are helping us out," says McIntyre. "They cover 20 sites that we wouldn't otherwise be able to study."

## Phoenix: *A City for the*

# Birds

By Diane Boudreau

BIRDS, BIRDS, BIRDS.

Phoenix is a city filled with birds.

Birds of many kinds. Birds of many colors.

Some of these birds are native to the Sonoran Desert. Some are birds that have moved here to stay. And some are birds that are just passing through on their way to nesting grounds in other locations.

How many different kinds of birds live in Phoenix? No one is sure, for now. But lots of people are watching and counting birds to find the answer. If you see a stranger lurking around your neighborhood with binoculars at dawn, don't be alarmed. Chances are, you've come across a volunteer birdwatcher taking part in an important study.

The study is part of the Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER) project at Arizona State University. Scientists in charge of the project want to find out what kind of impact all the new building and development is having on bird communities throughout the Phoenix metropolitan area.

About 90 local volunteers are helping to collect this information. Armed with binoculars and notebooks, they walk through Phoenix area neighborhoods at sunrise. They make note of all the birds they see or hear.

Joan Powers is a volunteer. "Initially I got stopped a lot," she says. "People get wary when you're walking around with a clipboard and binoculars at odd hours of the day." Today, people living in the neighborhoods patrolled by Powers recognize her. "I've been doing this for more than a year," she says. "Lots of people know me now. They ask, 'What new birds have you seen today?'"

"This study provides a unique opportunity to involve the public," says Mark Hostetler, a postdoctoral fellow at ASU who designed the bird survey project. "The majority of the population lives in urban areas. Urban areas are expanding dramatically. But we don't really understand them. Ecologists don't really focus on urban areas. We'd rather hang around in forests," Hostetler laughs.

The main goal of the bird study is to establish a pattern. Is that pattern consistent year after year? What are the mechanisms causing the patterns? For example, does housing density or road traffic affect bird populations in Phoenix?

Volunteers typically study a one-kilometer area divided into 10 segments. They make a note of all the birds they can see or hear. Some professional birders also participate. These bird-watching pros study four key habitats: golf courses, new residential neighborhoods, older residential neighborhoods, and desert remnants like Papago Park.



**CARDINALS** love the Sonoran Desert. Just like human "snowbirds," they flourish in places where winters are mild.

**THE BLACK-HEADED GROSBEAK** has a conical beak adapted for crushing seeds.

Charles Kazilek photo



Robert Ohmart photo

# What we know so far:

## CAP LTER BIRD SURVEY FINDINGS

**Building and landscape design** play a bigger role in attracting birds than zoning.

**Escaped pet birds** are thriving and breeding throughout the Phoenix area. “In my study area we have a population of peach-faced lovebirds that has been surviving and enduring. They obviously escaped out of someone’s house,” says Joan Powers. Peach-faced lovebirds are native to hot, dry African habitats. Arizona has all the comforts of home for them. Unfortunately, these sweet green birds with the rosy faces may pose a threat to native Arizona birds. They are potential competitors against woodpeckers and other birds. The lovebirds can take over giant saguaro cactuses. Powers says that lovebirds aren’t the only escapees she sees. Parakeets and parrots have also shown up on her list.

### REDTAIL HAWK

Daryl Abbott / Southwest Wildlife Rehabilitation Center



Phoenix Bird Survey Study data is available to everyone at <http://caplter.asu.edu/p012>. Visitors can learn exactly what species live where. To learn more about other CAP LTER projects visit <http://caplter.asu.edu/explorers/>

### PRAIRIE FALCON



George Andrejko photos

Most days, Powers sees about 15 of the same basic kinds of birds. But spring migration often brings in some odder species. ASU scientists hope to learn more about migrating birds that stop to rest in Phoenix.

“Nothing is known about stopover ecology,” Hostetler says. “We’ve seen lots of migrating birds coming through. There are more birds in Phoenix than outside the city. But the composition is different.”

The bird survey provides information that is useful to ecologists. ASU researchers say early findings of the study are that building and landscape design play a bigger role in attracting birds than zoning. In other words, the style of buildings and the type of vegetation around them matters more than whether they are houses, stores, or factories. This information could help designers plan more bird-friendly neighborhoods. Developers can use it to create communities that are more attractive to birds. The researchers are even trying to connect with realtors, encouraging them to use birds as a selling point.

ASU scientists think that involving the public is one of the best parts of this project. Many of the volunteers are retired people. Children and teachers from many local schools also help to collect information about birds. Teachers are trained to lead their students in conducting point counts. They stand in one place and count the birds in a 20-meter radius over a certain time period. Then they send the data in to the kids’ section of the CAP LTER Web site.


One goal of the project is to help connect urban kids to their environment. When he gives talks at schools, Hostetler often asks kids, “Where do chickens come from?” Many of them will name the local supermarket! “Urban life is great—we have all these conveniences—but it’s disconnected from nature. Understanding how humans affect the environment can help us minimize our impact.” Hostetler explains.



CACTUS WREN



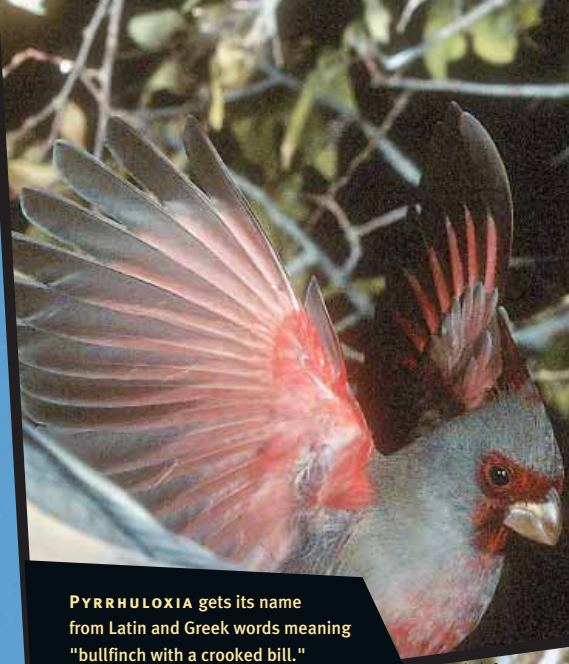
George Andrejko photos



**THE GILA WOODPECKER** is an important part of the Sonoran Desert animal community. Every spring, male and female woodpeckers work together to peck a deep hole in the thick stem of giant saguaro cactus or in the trunk of a cottonwood tree. Elf Owls and other birds make their nests in old woodpecker holes. Lizards and spiders and insects of many kinds also live in the old holes.

George Andrejko photo

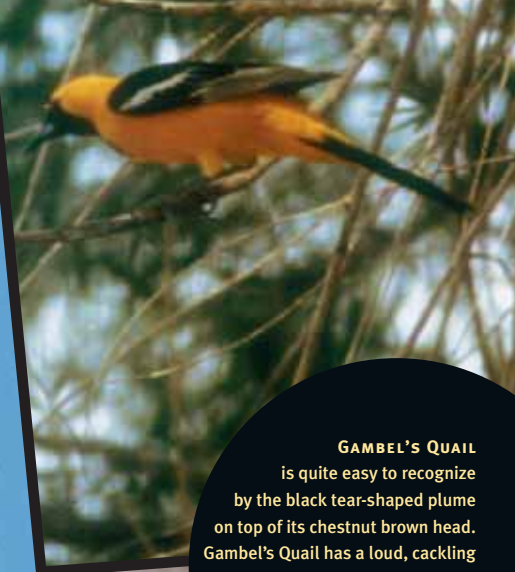
**ANNA'S HUMMINGBIRDS** live in the fast lane. To get the energy they need for hovering, hummingbirds must eat half their body weight in sugar each day. Some species beat their wings as fast as 80 times per second. Proportionally, a hummingbird's heart is the largest of any animal.



**PYRRHULOXIA** gets its name from Latin and Greek words meaning "bullfinch with a crooked bill."

Robert Ohmart photos

**NORTHERN ORIOLE** has a clear, flute-like call. It whistles single or double notes in short bursts.



**GAMBEL'S QUAIL** is quite easy to recognize by the black tear-shaped plume on top of its chestnut brown head. Gambel's Quail has a loud, cackling call that repeats three syllables. The second syllable has the highest pitch. The quail's ringing call is a true sound of the Sonoran Desert.



Robert Ohmart photo

# Numbers

## Tell The Story... Sometimes.

SCIENTISTS try to answer questions about the world around us. That is their job. To do this, they design experiments and make lots of measurements. The result of all this work is usually a long list of numbers. So how exactly do scientists turn all those numbers into meaningful answers?

## crossLink: numbers and biology

**More than 1 quintillion insects—1,000,000,000,000,000,000—live on Earth on any given day. By 2000, there were a little more than 6 billion humans—6,000,000,000.**

Scientists have discovered and described more than 900,000 different kinds of insects—more than 75 percent of all the known animals on Earth.

There may be as many as 30 million more kinds of insects yet to be discovered.

There are more than 30,000 known species of spiders. About 2,500 kinds of spiders live in North America.

BY DIANE BOUDREAU

THE NOT-SO-MAGIC TOOL THEY USE IS CALLED STATISTICS.

Statistics is a type of mathematics used to organize and understand data. Data are figures and symbols. Data include all the raw, unprocessed facts that scientists gather during their experiments and measurements.

Scientists use statistics to give meaning to all these raw facts and numbers. Statistics help scientists describe how things are right now. They also help to make predictions about how things will be in the future.

For example, ASU professor Harvey Pough wanted to know if he could help desert tortoises grow up faster by feeding them high-protein diets (See story, page 22). He started with 24 tortoises. Half were fed a protein diet and half a salad diet. Then he weighed all of the tortoises. The result was 12 different numbers for each tortoise group.

Pough used statistics to find out the average weight of tortoises in each group. He found that tortoises on the protein diet weighed an average of 800 grams. But tortoises in the salad group weighed an average of only 360 grams. Those results gave Pough an answer—the protein tortoises were definitely growing faster.

Statistics are especially useful when you need to learn about huge groups of subjects. For instance, ASU scientists working on the Central Arizona-Phoenix Long-Term Ecological Research project want to know how urban development and land use affects the number of bugs in Phoenix (See story, page 20). But they can't possibly count every single bug in all of Phoenix—it would take them forever! Instead, the scientists carefully chose a few sections of Phoenix to study. They count all the bugs in those small areas. The areas they chose are called a representative sample because, added together, all the areas represent the whole city.

The scientists make lots and lots and lots of measurements. Then they use statistics to find out what their sample says about the whole population of bugs in Phoenix. For example, if they find 47 beetles in their park area sample, they can estimate how many beetles there are in all Phoenix parks.

John Wallace is a 9th grade teacher at Mountain Ridge High School. His students used statistics to find out whether urban development has affected the number of bruchid beetles and palo verde trees in their school district.

Bruchid beetles lay their eggs on the seedpods of palo verde trees. The eggs hatch into larvae, which burrow into the pods and eat the seeds. The larvae grow inside the pods and come out as adult beetles.

Wallace's students collected seedpods from trees in their school district and from trees in a rural area outside Phoenix. They studied the rural area to get an idea of how things were before their school district was developed. The students counted the number of pods found in each area, and the number of beetle holes in each pod. The beetle holes told them how many beetles were born.

The findings for inside and outside the city were different. Using statistics, the students learned that this difference was significant—it was a real effect of urban development, not just random chance.

But were there more or less pods and holes inside the city? The answer was surprising.

There were more seeds inside the city than outside, probably because city trees are well irrigated. But what about the beetles?

“If all you had was the seed data you might think there would be more beetles, because the beetles eat the seeds,” says Wallace. “In fact, we found more holes per pod in the wild sample.”

After researchers analyze their data with statistics, they need to share it with other people. One of the easiest ways to do this is by creating a graph. Graphs take statistical information and make it into a picture. People looking at the graph can understand the data at a glimpse.

Let’s look at an example. Suppose a scientist was catching bugs in four different traps. On one particular day he counted the following bugs:

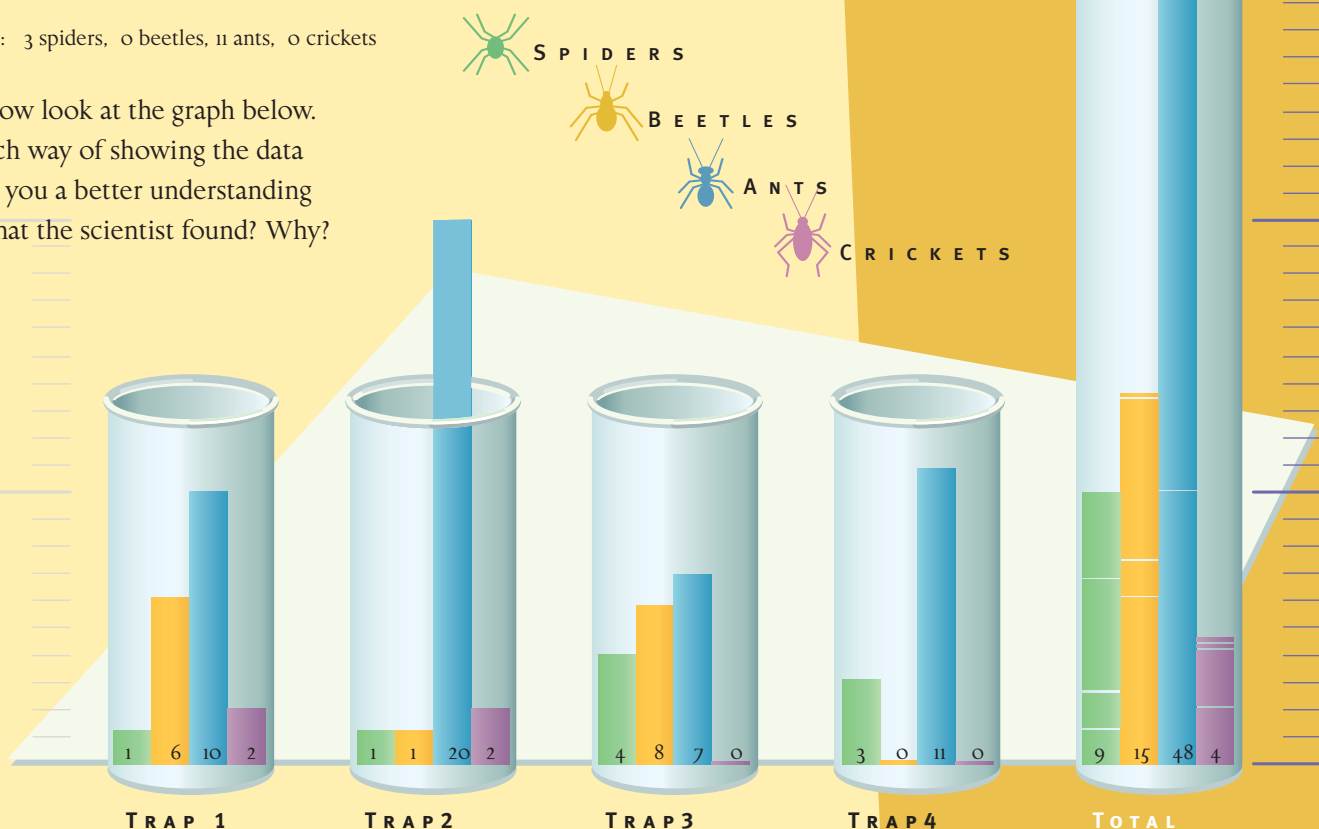
Trap 1: 1 spider, 6 beetles, 10 ants, 2 crickets

Trap 2: 1 spider, 1 beetle, 20 ants, 2 crickets

Trap 3: 4 spiders, 8 beetles, 7 ants, 0 crickets

Trap 4: 3 spiders, 0 beetles, 11 ants, 0 crickets

Now look at the graph below. Which way of showing the data gives you a better understanding of what the scientist found? Why?



### THOUGHT QUESTION

Scientists are not the only people who use statistics and graphs. In fact, statistics are used in almost every part of life. Your teacher uses statistics to come up with your average grade. Political polls use statistics to predict who will get elected president. Where else can you see statistics in use?

# Following the Fighting Females

by Dennis Durband

A GOOD HIKER visiting Arizona's 10,717-foot Mt. Graham would make plenty of noise to frighten bears away. Backcountry visitors would steer clear of javelinas and rattlesnakes to avoid provoking them. And no one would risk attracting lightning by carrying a metal fishing pole along a mountain trail during monsoon season. No one except Sarah Woodley, that is.



Woodley is a biology doctoral student at Arizona State University. Her scientific instincts overrule her instincts as a hiker. That's why she sits quietly in the forest. Woodley accepts the risks in order to study the aggression of female mountain spiny lizards.

For the past three years, Woodley has studied the behavior of these five-inch-long reptiles. She collects blood samples to study their hormones and observes the animals to see how they behave.

Lots of mountain spiny lizards live along the wood-lined creeks of Arizona mountains like Mt. Graham. The lizards are good candidates for scientific studies because they are easy to watch and easy to catch. Both male and female mountain spiny lizards are intensely territorial. They do furious pushups that send the message, "Here I am! Don't come into my territory!"

At least that is Woodley's interpretation of lizard body language.

Woodley studies how hormones influence female aggression in mountain spiny lizards. Female mountain spiny lizards are more aggressive than females of other lizard species. They will defend their territories by displays of pushups or by extending their dewlaps (throat flaps). They also charge and bite intruders. In male animals, the hormone testosterone leads to aggression. But scientists don't know why many females also behave aggressively, Woodley says.

During her last field study, Woodley worked in a forested area about 6,000 feet up the side of Mt. Graham. The mountain is located in the Coronado National Forest about 60 miles northeast of Tucson. Mt. Graham is black bear country, and Woodley has seen her share. The hiker in Woodley knew that she was supposed to make noise to scare them away. Scientist Woodley had to remain silent.

## THOUGHT QUESTION:

**In what other groups of animals do the females compete for food and territory?**



**crossLink:**  
BIOLOGY  
AND  
CHEMISTRY

**Hormones** are chemical messengers produced by endocrine glands. They travel through the bloodstream to reach different parts of the body. When they reach their destinations, hormones give instructions for controlling growth, metabolism, sexual reproduction, and other body processes. *Learn more about hormones and lizard behavior—Visit the website at <http://askabiologist.asu.edu/research/tlizards>*

She was more wary of the javelinas—because of their sharp canine teeth—and the “jumpy” cattle that graze through the forest.

Snakes often ate her lizard subjects while she was studying them.

Monsoon thunderstorms filled the sky late in the afternoons. Woodley got soaked many times. Despite the attractions and distractions, she made her observations and collected 60 female spiny lizards over a seven-week period.

In a laboratory at ASU, Woodley performed surgery on each of her captured reptiles. She removed some of the lizards’ ovaries—glands that produce eggs and female hormones. She gave others a testosterone implant.

A second group of lizards served as controls. The control group underwent fake surgery. Woodley didn’t remove or implant anything on these lizards.

None of the lizard surgeries harmed the animals. They were put to sleep so they didn’t feel any pain. Surgery only lasted about 15 minutes, and all of the lizards survived. Each patient went home the day after surgery. Each was marked with a harmless paint stripe for identification.

Woodley says the lizards acted skittish for several days. So she waited three weeks before making new behavioral observations. During those three weeks, she visited the site every other day to help the lizards get used to her presence.

Woodley watched to see how the surgically altered females reacted to intruders. She used a fishing pole and dental floss to place intruders on rocks in the territories of other females.

Females without ovaries showed a decrease in aggression. Since ovaries are the main source of the hormone estradiol, Woodley believes that estradiol plays some role in aggression. However, the female lizards with testosterone implants rated high in displays but low in charging intruders. The testosterone wore off over time. Woodley thinks the hormone may have caused females to exhibit male-like courtship displays.

Fake surgery did not seem to change the lizards’ behavior. More than 70 percent of those females charged and bit intruders as usual.

Woodley’s research is important because most scientists have assumed that aggressive competition is a characteristic of males. They have ignored the large number of situations where females aggressively compete.



## What is a Control Group?

Control groups are an important part of many scientific experiments. Researchers use control groups to find out if a treatment really has an effect. Sometimes, study subjects act differently after treatment just because they know they got treated.

Suppose that you go to your doctor and tell her that you can’t sleep at night. She gives you a pill to help. You go home, take the pill, and fall right to sleep. The pill did the trick, right?

Maybe. Or, maybe you believed the pill would work, so you quit worrying about falling asleep. You got so relaxed you had no trouble sleeping. It was your state of mind, not the pill itself, which helped you.

The way to find out what really worked is to conduct an experiment using a control group. In this type of experiment, about half of the subjects would receive the real sleeping pill. The rest would receive a fake pill, usually made of sugar. The fake pill is called a placebo. None of the subjects would know which pill they got.

After the experiment, the researcher would compare the results. If the people taking the real pill fell asleep, but the control group didn’t, then we would know the pill works. If both groups fell asleep, then we would know that the act of taking the pill, not the pill itself, was what worked. This is known as the “placebo effect.”

Even animal researchers often need to use control groups. For instance, Sarah Woodley wanted to know if removing a lizard’s ovaries would change the lizard’s behavior. She needed to be sure that the loss of ovaries, not the experience of capture and surgery, was what caused any change. Woodley used a control group of lizards. The “control” lizards went through surgery, but kept their ovaries.

Can you think of some reasons why a lizard might be less aggressive after surgery, even if the surgery is not quite the real thing? —DIANE BOUDREAU

# Thermoregulation: Hot

## Enough For You?

ANIMALS OF ALL KINDS live in hot, dry South-western deserts.

These creatures have adapted to survive sizzling summer days and frosty winter nights. To stay cool, a desert animal must avoid and shed heat. To stay warm, the creature must gather and store heat in some way.

THE MANAGEMENT OF BODY HEAT IS CALLED THERMOREGULATION.

Without proper thermoregulation, animals cannot survive. To understand thermoregulation, it is important to know a little bit more about heat.

In the 1700s, scientists thought of heat as a mysterious fluid, which they called "caloric." They thought that heat flowed from a hot into a cold substance in the same way water flows from a full into an empty cup. For more than 100 years, the caloric idea helped to explain observations about heat.

Ideas changed in the mid-1800s. New observations about heat could not be explained in terms of the caloric idea. Today, heat is just one part of the modern theory of thermodynamics. The theory says that heat is a form of energy, not a mysterious fluid. But we still say that heat "flows."

Scientists know that heat influences temperature. When a substance contains lots of heat, it is hot. When it contains little heat, it is cold.

The amount of heat in a substance is called its *heat content*. When a hot substance is put in contact with a cold substance, both substances eventually become warm. They reach a state called "thermal equilibrium." Heat from the hot substance flows into the cold substance until it is balanced between the two. As a result, both substances reach the same temperature. That temperature stays the same over time.

If left alone, heat always flows from hot to cold. This is the direction of spontaneous flow. "Spontaneous" means that the flow happens all by itself. No usable energy is consumed.

Substances or materials often come in contact with one another. During that contact, heat can flow from one substance to the other. This process is called *conduction*.

Any substance, including the skin, feathers, or fur of desert animals, is always in contact with its surroundings. That substance is always exchanging heat with those surroundings. If heat is added faster than it is lost, the heat content and temperature of that substance will increase. If heat is lost faster



The  
Wright  
Stuff  
BY DAVID WRIGHT

The *caloric* idea lasted as an explanation for heat because it described many commonly observed effects of heat. **We now know that heat is the energy of moving molecules.** This explains the most careful observations we can make of heat effects. The molecules in liquids and gases bounce off each other like bumper cars. The molecules can't move around in solids. They vibrate in place, as if held together by tiny springs.

### Examples of average body temperatures

**BIRDS: 100-112° F**  
**RABBITS, SHEEP AND CATS: 102.2° F**  
**HORSES: 100.4° F**  
**WHALES: 95.9° F**  
**HUMANS: 98-99° F**

(IN AMERICA AND FRANCE, "NORMAL" IS SET AT 98.6°. IN GREAT BRITAIN, 98.4° IS CONSIDERED THE NORMAL POINT).

SOME MAMMALS HIBERNATE IN THE WINTER AND DROP THEIR BODY TEMPERATURES DURING THIS TIME. THE MOST EXTREME EXAMPLE IS THE **ARCTIC GROUND SQUIRREL**, WHICH CAN DROP ITS BODY TEMPERATURE TO **28.4° F** WHILE IT HIBERNATES.

PERSPIRATION is efficient for cooling, but only if the air is dry. If the air is humid, the evaporation process is slow. Heat is not removed quickly. Unfortunately, perspiration requires a large amount of water, which usually is scarce in the desert.

Many desert animals do not have sweat glands. Birds and rodents, like dogs, must pant to cool themselves. When they inhale dry air, water found on the linings of the lungs evaporates. The evaporating water absorbs heat from the lungs. Heat is exhaled along with the water vapor. But if these creatures become dehydrated, they will overheat.

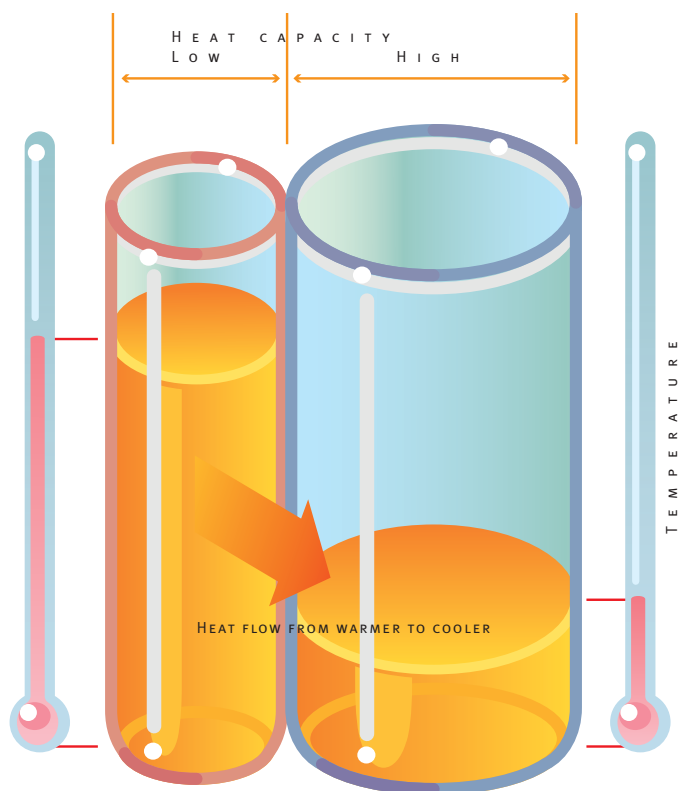
than it is added, heat content and temperature will decrease. If heat is added and lost at equal rates, the heat content and temperature will not change.

Every substance has a different ability to hold heat. This ability is called the *heat capacity* of the substance. Different substances have different heat capacities. As a result, they can have different heat contents, even though they may exist at the same temperature.

Imagine that heat really is fluid and that a substance is a cup. The diameter of the cup represents its heat capacity. The amount of fluid in the cup is the heat content. The height of the fluid in the cup represents the temperature.

The desert is hot because the soil absorbs heat from intense sunlight. This is called radiant heating. Sunlight is a form of radiation that contains many different kinds of light, including infrared light. Infrared light carries heat and is not visible to the human eye.

The same heat content can result in different temperatures, depending on the heat capacity of the substance.

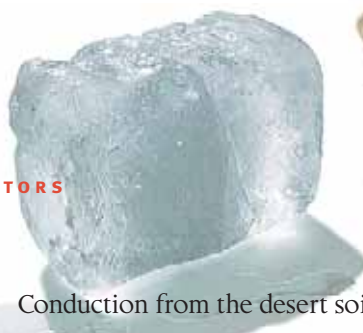


This is what sweat looks like on the surface of your skin — enlarged thousands of times by electron microscope. The image was made from a latex rubber mold of a fingerprint. Living things cannot be viewed in an electron microscope because the energy of the electron beam used to illuminate the subject would fry it!





## CONDUCTORS



## INSULATORS



Heat flows quickly through some substances. These are called **thermal conductors**. Heat flows slowly through substances that are **thermal insulators**. The flow of heat into or out of a substance depends on conduction. The storage of heat depends on insulation. Thermoregulation depends on both conduction and insulation.

**Substances that are good thermal conductors:** metal or water.

**Substances that are good thermal insulators:** wood, bone or rock.

**What characteristics of these materials affect heat flow?**

Desert birds, like this turkey vulture, often soar effortlessly for hours by riding on thermals, the updrafts of rising air created by convection. By gliding on thermals, the birds conserve precious energy as they hunt for food.

TEMPERATURE IS A MEASURE OF HEAT. THERE ARE SEVERAL DIFFERENT TEMPERATURE SCALES.

The **Fahrenheit** scale is the oldest system for measuring temperature, still common in the United States. It was invented by German physicist named Daniel Gabriel Fahrenheit in 1724. He set the **freezing point of water at 32 degrees**, and the **boiling point at 212 degrees**.

Anders Celsius invented the Celsius scale in 1743. He set the **freezing point of water at 0 degrees** and the **boiling point at 100 degrees**. This system is now used in most countries and among scientists everywhere. It is also called the Centigrade scale.

The **Kelvin** scale measures the ultimate extremes of temperature. It was invented in 1848 by Lord William Thomson Kelvin. In the Kelvin system, zero degrees — or “**absolute zero**” — is the temperature at which there is no molecular motion and therefore, no heat at all. There is no temperature colder than absolute zero. Absolute zero is equal to -273 degrees Celsius or -460 degrees Fahrenheit.

Conduction from the desert soil causes the air to get hot. The air expands. As it becomes less dense and more buoyant, the hot air rises. To replace the rising hot air, cooler air from above sinks to the desert floor. That air then absorbs heat and the cycle continues. When heat moves because hot air rises and cool air sinks, the process is called *convection*.

Desert animals have adapted ways to stay cool during the hot desert day. They stay in shade or find a cool place underground to avoid radiant heating and conduction from the soil. Most desert animals are nocturnal, which means they are active only at night. This is thermoregulation through behavior.

Thermoregulation also depends on the way in which heat interacts with matter. Substances can exist in solid, liquid, or gas form.

The form, or *phase*, of a specific substance is determined by its heat content. Think about water. If ice absorbs heat, it will melt to form liquid. If the liquid absorbs heat, it will evaporate to form steam or vapor. However, if that water vapor loses heat, it will condense to form liquid. If the liquid loses heat, it will freeze into ice.

The change between phases is called a transition. For animals, evaporation is an important process for cooling—melting, freezing, and condensing are not practical methods for thermoregulation.

For example, if an animal has enough water in its body, it can use evaporation to stay cool by perspiration (sweating) and respiration (breathing). Animals with sweat glands perspire to cool large areas of skin. Water is secreted through pores in the skin. When it evaporates, the water vapor carries away heat from the skin.

Lizards, snakes, and other cold-blooded animals cannot generate body heat from the energy in their food. To stay warm, they absorb the heat they need from the surrounding environment. They absorb heat directly from sunlight. They also use conduction to absorb heat from the hot desert soil. They retain that heat by insulation.

Coyotes, javelinas, rodents, birds, and other warm-blooded desert animals also absorb external heat. But they also use chemical energy from food to generate large amounts of internal body heat.

As long as food is plentiful, warm-blooded animals have a distinct advantage for thermoregulation. Warm-blooded animals can stay warm even when it is cold outside for long periods of time. On the other hand, cold-blooded animals don't need as much food to survive extreme temperatures because these creatures don't use the energy from their food for thermoregulation.